

Analysis and Response
To
Motorola's
"Interference Technical Appendix"
Dated February 2002

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INTRODUCTION

The referenced Motorola document entitled “Interference Technical Appendix”, issue 1.41, dated February 2002, was published as an effort to describe potential interference issues experienced by system operators and users in the 800 MHz band. The paper does a commendable job of educating the reader about the challenges faced by operators of large, wide-area multi-frequency radio networks. However, it does not go far enough in commenting on the technology issues that have contributed to Nextel’s current notoriety as a major contributor to interfering with Public Safety operations.

This analysis will use the Motorola document as a source of information, which will be used to question some of the known technological system architecture deficiencies within iDEN, which contribute to the interference problem.

COMMENTS

Before getting into details, it is important to set the stage for the issues as they now exist. The following is a listing of “features” of the early Trunking, Cellular and Nextel/iDEN systems (the earlier NEXTEL “MIRS” architecture is not discussed):

Trunking Systems (800 MHz)

- Introduced in the 1970's, analog only
- Small systems, 5-10 channels, cavity combiners
- “New” spectrum, noise limited only
- Large-area coverage, single tall site
- Mobile units were modified crystal-based sets
- Mobile receivers had very good front-end selectivity
- Most users were single-system users
- Some subscribers could use “interconnect” mobile-phone-like services
- Only active channels were keyed

Cellular Systems

- Introduced in the mid-1980's, analog only
- Clear spectrum, no interference limitations
- AMPS architecture had built-in interference-control tools
- Large channel set groups, cavity combiners
- Tall sites were the norm, aimed at the horizon
- Systems were designed with a grid pattern, minimal reuse
- Mobile-unit-only subscriber sets (no portables), efficient antennas
- Mobile receivers had good front-end selectivity
- Only active channels were keyed

NEXTEL (iDEN) Systems

- Introduced in the mid 1990's, replacing MIRS
- Multi-site, wide-area use (dispatch & interconnect)
- Limited channel sets
- Tall sites, high power, hybrid combiners due to “ad hoc” channel spacing
- High power portables
- Most subscribers were dispatch users
- All channels keyed, all the time

Evolution of Services

The eventual evolution of these three distinct services/technologies has been driven by subscriber demands; the earlier subscriber distinction between the “business/dispatch user” (SMR/NEXTEL) and the “yuppie on the cellphone” has blurred and the services offered have become intertwined.

It is probably safe to say that Trunking (SMR) systems have evolved the slowest, partially due to the stability of the customer type (dispatch). Synthesized mobile radios and portables allowed SMR customers to subscribe to multi-SMR systems, giving them a broader coverage area. The user had to manually switch from one system to another as they approached the borders of the systems. The introduction of narrowband technology in the 900 MHz SMR band was one of the major innovations. Even though the frequency band change was not a great jump, the technology associated with 900 MHz brought with it new challenges and problems. The basics of trunking architecture still govern the setup and operation of these systems. Public Safety trunked systems fit within this category, with some added bells and whistles (“digital” capability being the major differentiator).

Cellular systems grew at a phenomenal rate in the 1990’s and the technology strained to keep up with demand. While there was no doubt that the original concept of “cellular” could handle growth due to the tools built into the architecture, frequency spectrum availability could not keep up with the subscriber growth. (The FCC auctioned off 1.9 GHz PCS frequencies in the mid-1990’s; most of these systems became operational in the late 90’s.)

While struggling with the evaluation of TDMA in the early 1990’s, large systems such as New York City and LA were in a continuous “cell-split” mode, building more and more small cell sites, and further increasing the ability to reuse the limited spectrum available. An early miscalculation made by the carriers was that the conversion to “digital” brought about immediate capital expenditure relief (“stop building cell sites”). They didn’t count on the fact that a high quality digital call needs very consistent and stable signal strength levels. Adding digital channels to the mountaintop site didn’t deliver high quality calls in the same areas where analog was acceptable. The result? The conversion to digital required even more sites.

Interestingly, the lack of a “digital flip phone” in the early TDMA days caused more growth in the analog side of the network just as analog system capacity was being replaced by digital radios! The emerging consumer market was enamored by the StarTac, which was only available as an analog unit for many years.

Nextel's network grew by fits and starts, often driven by the acquisition of new channel sets and operating areas as SMR's were purchased and consolidated into the iDEN network. The introduction of iDEN as the fix for MIRS problems further aggravated the situation because, just like the cellular operators learned, plugging a digital radio in place of an analog radio doesn't bring about a miraculous increase in capacity; other changes have to be made. Unfortunately, the iDEN architecture was nowhere near as flexible and feature-rich as cellular in regards to signal and interference control. While cellular networks were able to grow and manage internal interference, Nextel had no way to gracefully grow the network to meet demand, especially when "interconnect" usage began to outgrow dispatch usage (the "flip phone phenomena", again).

This brings us to the present.

The next few pages will refer to the Motorola paper to raise questions and point out issues, which might not be totally clear, or are not mentioned at all.

Page 3

The color chart does a very good job of visually stating the spectrum issue. Simply put, if every licensee stayed within their spectrum band and operated their networks within that spectrum, as licensed, many of the problems being discussed would not exist. Cellular carriers have operated their systems under the “AMPS” rules since the inception; SMR operators have their fixed assignments and operate under the established system architecture rules; only Nextel has tried to make a trunking system operate like a cellular system, while following the rules of neither service.

Page 4

The “near-far” scenario is described, but with little reference to how iDEN technology uniquely contributes to this problem, even within its own networks. This is rarely a problem with properly engineered cellular systems.

Page 5

The explanation about hardware contributing to some of the current problems is very valid. The question raised here is “why do current 800 MHz band radios have to have bandwidths in excess of 60 MHz (transmit) and 18 MHz (receive) if for no other reason than manufacturing simplification?” Is it not evident that the interference issues have arisen as these radios have become more prevalent in the field? Public Safety users are the most implicated due to their insatiable appetite for the latest technology and the newest radio features, coupled with their tendency to spend as little money on the network’s infrastructure.

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Table 3 lists some of the ideal and not-so-ideal situations that develop as frequency division-type networks have grown (e.g., AMPS, TDMA, GSM, iDEN). Some statements are unclear in regards to iDEN capabilities. Several examples follow:

Transmitter Filtering – iDEN uses hybrid combining in order to allow for a “dynamic frequency plan”. Hybrid combining (1) wastes RF energy as heat, and (2) allows transmit signals to mix causing IM (intermodulation) products and OOB (out of band emissions). This type of combining is claimed to be most accommodating of the Dynamic Frequency Allocation feature, yet cellular carriers

have used auto-tune cavity combiners to do this for years, albeit within a more controllable frequency plan.

Tower Heights - low antenna sites are typically operated at very low RF signal power levels in the cellular configurations; “microcells” operate at signal levels of less than 1 Watt ERP. IDEN does not have the dynamic range in their base equipment to power down; conversely, as more channels at a site are required for capacity, the multiple hybrid combiners require the transmitters to run high power levels anyway. The higher power also helps with in-building penetration.

Not mentioned: cellular AMPS architecture allows a channel to be keyed only when it is needed to provide capacity. The system also allows channel selection in a bottom-up or top-down list, allowing further flexibility to the control of interference within the system. IDEN does not make use of these tools. All channels are keyed, all of the time. Therefore, even when iDEN subscribers are not using the network, the iDEN network is creating IM and OOB problems to others.

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The chart on this page is misleading since it doesn't clarify the technology differences. For example, cellular analog networks utilized separate transmitter exciters, amplifiers, and cavity combiners. The technology evolved into the use of low-powered exciters feeding a wideband linear power amplifier which then transmitted through a bandpass SAW filter. TDMA and analog systems shared this technology evolution.

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A statement is made that says “...SMR's frequently use[s] broadband hybrid combiners to allow frequent frequency changes without requiring site visits”. What SMR operator, except for Nextel, experiences the need for “frequent frequency changes”?

In further explaining the chart on the previous page, another misleading statement is made: “The duty cycle indicates whether the transmitter(s) are continuous as cellular type deployments require or intermittent as typical of LMR systems use. Note that when a trunking system is involved, the control channel may be continuous while the voice channels are intermittent”. This is blurring the issue...duty cycle and operational cycle are being mixed up. All commercial radio transmitters are rated for continuous duty; cellular channels are NOT operated continuously but only when required. IDEN channels are operated continuously, even when not needed.

The frequency coordination issue is also muddled. All cellular operators coordinate within and outside of their networks on a regular, continuing basis. This has been done since day-one, per FCC requirements. As inter-system handoff became possible, coordination was even more important.

It is pointed out that the cellular carrier can make changes when "...the interference gets strong enough, the system will be able to provide an alternative resource that isn't being interfered with", yet nothing is stated in regards to iDEN capabilities in this regard (there are none). Some cellular systems can automatically "seal" (turn off) a channel that is experiencing interference, taking it off the site's assignment list. Another cellular feature is "directed retry" which will pass a call request to a neighboring site, thus adding to the ability to manage channel assignments and minimize network interference.

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The chart and description for "Case 1b" clearly summarizes the existing Nextel/Public Safety issue. The "Cellular TDMA" title in the chart could read "iDEN".

Page 27

The plea for higher receiver (portable PS radio) IM performance is valid and has been supported by the cellular carriers who have been involved with the interference issue. Is Motorola, the manufacturer, listening?

The balance of the scenarios are interesting, but the chance of them occurring is magnitudes less possible than the scenario explained in Case 1b.

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We now get into recommendations on how to fix the problems described. Again, as has already been pointed out, there is a lack of specifics related to the internal working of iDEN which might help to highlight some of the challenges.

The number one rule is to make sure "your own house is clean" before looking elsewhere.

It is evident by the way iDEN combines channels and uses tight frequency separation between channels that internal system problems are potentially more prevalent than external problems. Lossy hybrid combiners require large amounts of RF energy to deliver sufficient signal levels. One iDEN scheme calls for 3 dB combiners for every 4 channels at a site. As soon as the fifth channel is needed, another 3 dB combiner is added. The result: as more capacity is added, the RF footprint of the site begins to decrease. As the transmitters are powered up to

compensate, the IM and OOBE potential increases. Hundreds of Watts of RF energy (much of it lost as heat) is generated to deliver several Watts of signal to the antenna. The costs related with the need for increased electrical power and air conditioning to generate and remove the heat are high. Equipment space is increased, adding further costs to operating the system.

Perhaps as a self-audit, Nextel should respond to the “Methods to Reduce Interference of Specific Types” (by item):

- A. Are all sites operating within maximum ERP to satisfy licensing and government environmental requirements (NEPA)?
- B. Is sufficient attention being given to frequency planning? What tools are being used?
- C. Shuffling frequencies is an easy fix to suggest, but at whose ultimate cost?
- D. This is at the heart of the iDEN problem...how about lowering the power output of channels that are not providing service, or shutting them off entirely? This minimizes the occurrence of IM and OOBE.
- E. Changing antennas while still radiating high signal levels might not be worthwhile.
- F. This is a simplistic fix, since changing antennas will also impact the provided coverage. Customers are sensitive to the “before and after” effects of these band-aid fixes.
- G. This suggestion is also simplistic in that it promotes the never-ending issues of intrasystem interference and building sites just to mask interference.
- H. Same as G.
- I. Use cavity combiners (!). Why not? Coupled with D., there might be hope!
- J. More sites is not always the answer, especially when zoning issues prevail.

E through J are the challenges faced every day by the Nextel RF Engineer. Trying to balance the need for increased capacity and coverage while trying to establish channel assignments which minimize IM and OOBE and also allow the most flexibility in capacity distribution is very difficult. It is not unusual in large iDEN systems to experience “no service” when standing in front of an iDEN cell site. This is often due to the combination of IM products from that site, overload in the subscriber’s portable, and interference from a co-channel site.

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The “Possible Actions...” section is a checklist for the Public Safety industry. These operators still think their networks can be sophisticated enough to use exotic data systems and speech encryption and still only need one 500-foot tower to serve the entire target area. As soon as they begin designing their networks as “systems” (like the cellular people have always done) then perhaps they will resolve many of the issues they now face. Is Motorola going to take their own advice?

SUMMARY

It is evident that the problems faced by Nextel have been self-imposed from the beginning. Trying to patch together frequency assignments that were made with a certain use and technology in mind is a difficult challenge, even if it only causes internal system problems. But now it is clear that everyone has been dragged into Nextel's nightmare. There is no doubt that rearranging the entire 800 MHz band would help matters to a certain degree; but, will it actually make the current problems go away? The consensus is that the answer is "No!".

Motorola has patched together the iDEN architecture while ignoring many of the very tools and features that would make it work better. I was once told that the Motorola iDEN development team did not have one engineer with cellular system experience on the team.

It had been hoped that a technological leap would be made in both the basic architecture and equipment form factors, but that will probably not happen quickly. Whatever Nextel's next technology direction might be, it must take into account the tools and features which have enabled cellular networks to grow more quickly and serve more subscribers than Nextel ever could. If Nextel is not willing to discuss future technology improvements in relation to this current Public Safety interference issue, then perhaps this radical frequency-swap proposal should be placed on hold. The very people who will be most impacted are the ones who have been going by the rules.

Nextel has technology issues which need to be addressed before the entire 800 MHz spectrum gets turned upside down. Instead of proposing an external fix (complicated and costly to others) why not spend the money and effort to clean up their own (archaic) system architecture? Otherwise, the problem will still be there after the dust settles. Wouldn't it be in Nextel's best interests to operate an efficient, cost-effective and flexible network architecture?

Public Safety, which probably consumes slightly less spectrum than the federal government, might also have to look more closely at technology to serve their needs than just "more frequencies". How do they explain the Lowband, VHF and UHF frequencies that they continue to hold yet not use? Do they really think that the 700/800/900 MHz networks of the future are going to give them ubiquitous coverage? Do they think that in-building coverage is going to happen magically when they get more spectrum? While there has been a lot of talk since 9/11/2001 about interoperability and reliable public safety communications, there has been little real action taken. Haven't they seen what the cellular/PCS carriers (and, yes, even Nextel) have gone through to build out their networks in the face of public opposition to "more towers"? Perhaps some of their interference issues are self-caused.

Finally, Motorola has a responsibility to all of the above. The “Technical Appendix” raises a lot of good points and offers some useful suggestions to improve service. But, someone has to take that paper and agree to implement the changes. Ultra-wideband radios are built by Motorola; many of the existing SMR systems are Motorola-based; Nextel is an exclusive iDEN infrastructure user; most large Public Safety networks, present and future, will utilize Motorola products. It is evident that Motorola has as much at stake as Nextel as far as delivering well-designed and engineered systems.